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A 4.5-acre pond serves as a test site for the effects of fishing, emigration, and natural mortality on white shrimp.

White Shrimp *(Penaeus setiferus)* Population Trends in a Tidal Marsh Pond

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ABSTRACT

Ketchen's modification of the Leslie fishing success method was used to estimate initial population and rates of immigration, fishing, and other losses (emigration and natural mortality) in a white shrimp (Penaeus setiferus) *population in a Texas tidal marsh pond. The significant decline in catch rates of marked and unmarked shrimp during the experiment was due to fishing and other causes (emigration and natural mortality), but the reduction due to fishing was less than that due to other causes. We believe that this or similar methods offer considerable promise in future studies of this nature.*

INTRODUCTION

The growing need for more intensive management of the shrimp resources of the Gulf of Mexico has stimulated renewed interest in the study of penaeid shrimp population dynamics. Comparison of the rates of fishing and natural mortality is of particular interest, since such information is essential to determining the relative influence of inshore (estuarine) and offshore fishing on total yield. Information on population size and rates of migration is also needed. Since changes in shrimp populations take place very rapidly, we are using "fishing success" methods based on short-term sequential sampling or fishing in conjunction with concurrent mark-recapture experiments to obtain estimates of population and rates of fishing, natural mortality, and migration. We are conducting our initial tests of this technique in estuarine areas in which we control the intensity of fishing (sampling). If successful, we plan to expand the use of the technique to areas in which commercial and sport shrimping occur.

According to Ricker (1958), fishing success methods are applicable when fishing is of sufficient intensity to reduce significantly the catch per unit of effort (C_t/f_t, in which t is an interval of time). This concept appears to have originated with Leslie and Davis (1939), who related the decline in catch per unit effort to cumulative catch. Later DeLury (1951) related the decline in the logarithm of catch per unit effort (ln $[\ C_t/f_t]$) to cumulative effort (E_t). DeLury also recognized that concurrent mark-recapture experimentation could provide valuable additional information on changes in catchability and on trends in population. Ketchen (1953) later applied this principle to estimate initial population, emigration, and immigration in a population of lemon soles (*Parophrys vetulus*), in which it was assumed that there was no significant excess of recruitment over natural mortality (or the reverse).

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Our study applied Ketchen's (1953) modification of the Leslie method to estimate initial population and trends in a population of white shrimp (*Penaeus setiferus*) in a tidal marsh pond. Although intensity of fishing was controlled in our experiment, we believe that this method, or similar ones, holds considerable promise for use in areas where commercial and sport fishing occur.

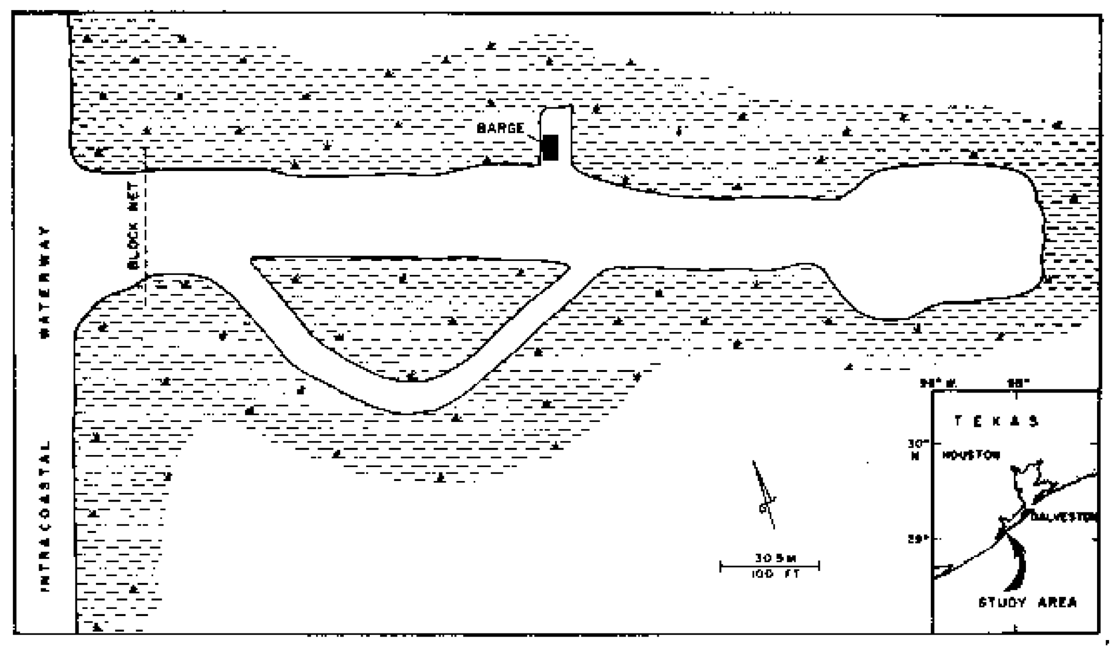

Figure 1.—Map of study area.

STUDY AREA AND METHODS

The study was conducted during 6-9 November 1972, in an unnamed tidal marsh pond in Brazoria County, Texas. This pond, 4.5 acres in size, is located 3 miles northeast of Freeport and is connected to the Intracoastal Waterway (Figure 1). Average depth at MLW is approximately 4 feet. This pond was selected because it has a well-defined shoreline that seldom floods at high tide, a trawlable bottom, and a narrow entrance that can be blocked with netting.

To prevent immigration and emigration of shrimp we blocked the entrance (Figure 1) on October 6 with netting (½-inch stretch mesh). This was left in place until the study terminated. Shrimp were collected the following day with a 10-foot flat otter trawl (½-inch stretch mesh) towed with a 16-foot skiff powered by an 18 hp outboard motor. A sample of shrimp was measured (total length, tip of rostrum to tip of telson), and those remaining were held in aerated containers until 2,054 were marked by injection with 2% neon red fluorescent pigment as described by Klima (1965). To minimize marking mortality, we attempted to mark only shrimp 40 mm in total length or larger. Marked shrimp were retained in a holding pen (within the pond) of nylon netting (¼-inch stretch mesh) until marking was completed. Of the shrimp marked, 2,004 were liberated randomly throughout the pond. The remaining 50 were kept in the holding pen for the duration of the study to measure marking mortality; 50 unmarked shrimp also were held in the pen as a control.

On both 8 and 9 November, between 0815 and 1330, 23 sequential 5-minute tows were made with the otter trawl. The 46 samples were examined under ultraviolet light to identify marked individuals, and the numbers of marked and unmarked shrimp captured in each tow were recorded. Total length of all marked shrimp and up to 50 unmarked shrimp from each tow was measured. Length-frequency distributions of these and the initial sample of shrimp collected prior to marking are shown in Figure 2. All shrimp caught (regardless of size) were used in our analyses.

RESULTS AND DISCUSSION

We estimated initial population ($\hat{N}$, Table 1) using Bailey's (1951) modification of the Petersen formula

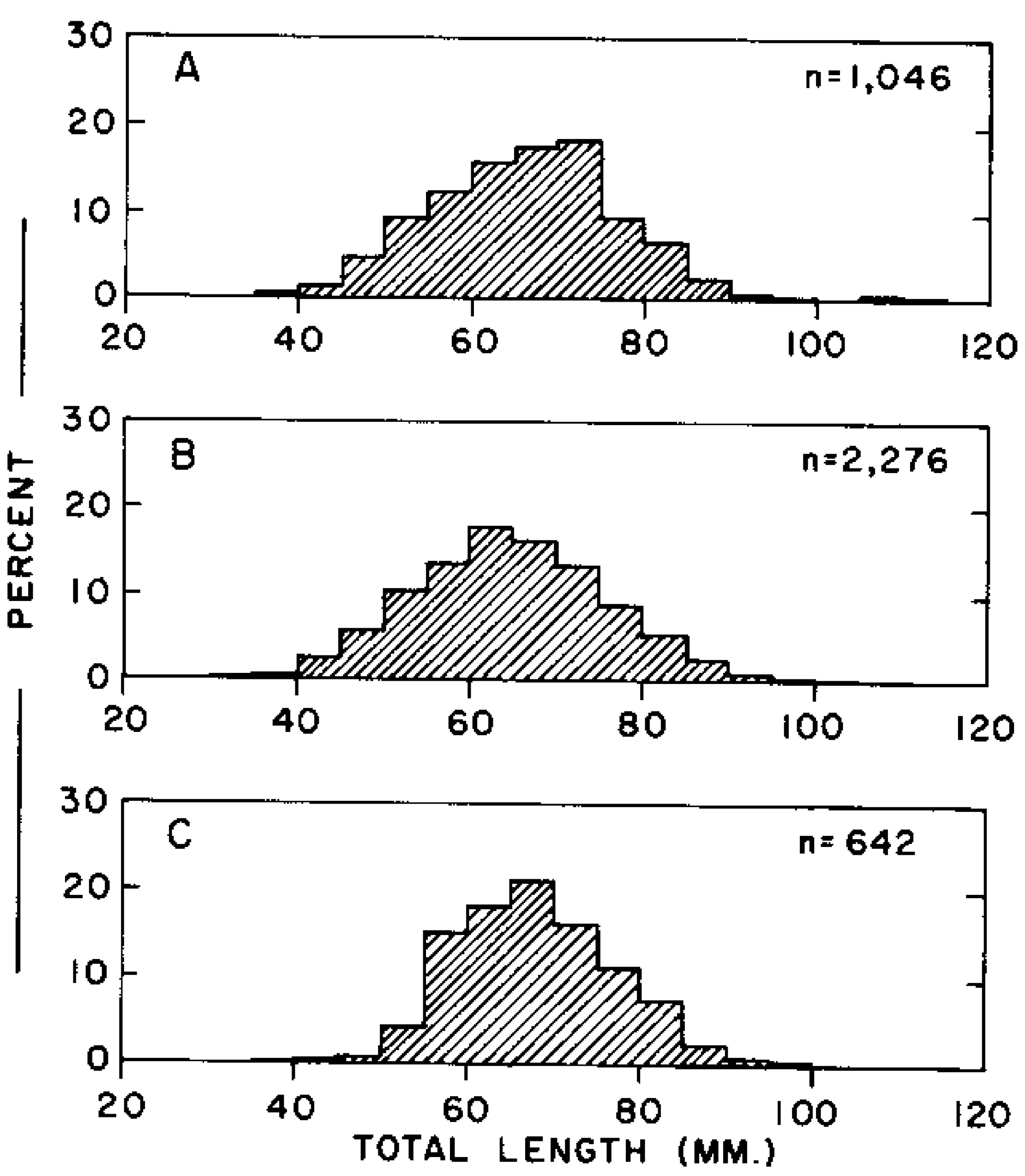

Figure 2.—Length-frequency distributions (in percent) of white shrimp: (A) Shrimp collected prior to marking; (B) unmarked shrimp caught during the study; and (C) marked shrimp caught during the study.

$$\hat{N} = \frac{M(C+1)}{R+1}$$

in which

M=Number of marked shrimp released

C=Number of shrimp caught or sample taken for census

R=Number of recaptured marked shrimp in the sample.

The 95% confidence limits for the true population, N, were estimated from the large sample variance formula of Bailey (1951).

We calculated the least squares regression of catch on cumulative catch for both unmarked and marked shrimp (Figures 3 and 4) by

$$C_t = cN_a - cK_t$$

and

$$R_t = c'M_a - c'J_t$$

in which

C_t = Number of unmarked shrimp caught in tow t

R_t = Number of marked shrimp caught in tow t

c = Catchability of unmarked shrimp

c' = Catchability of marked shrimp

N_a = Apparent initial population of unmarked shrimp

M_a = Apparent initial population of marked shrimp

K_t = Cumulative number of unmarked shrimp caught, to the start of tow t

J_t = Cumulative number of marked shrimp caught, to the start of tow t.

We used catch rather than catch per unit effort because effort was constant. In this case, t can refer to tow or time interval because duration of each tow was held constant. Estimates of apparent initial population, initial population, and instantaneous rates of fishing, "other losses", and immigration were obtained by the methods of Leslie and Davis (1939) and Ketchen (1953) as described by Ricker (1958).

The instantaneous rate of fishing, p, was estimated by

$$p = \frac{M_a\,(c'f)}{M}$$

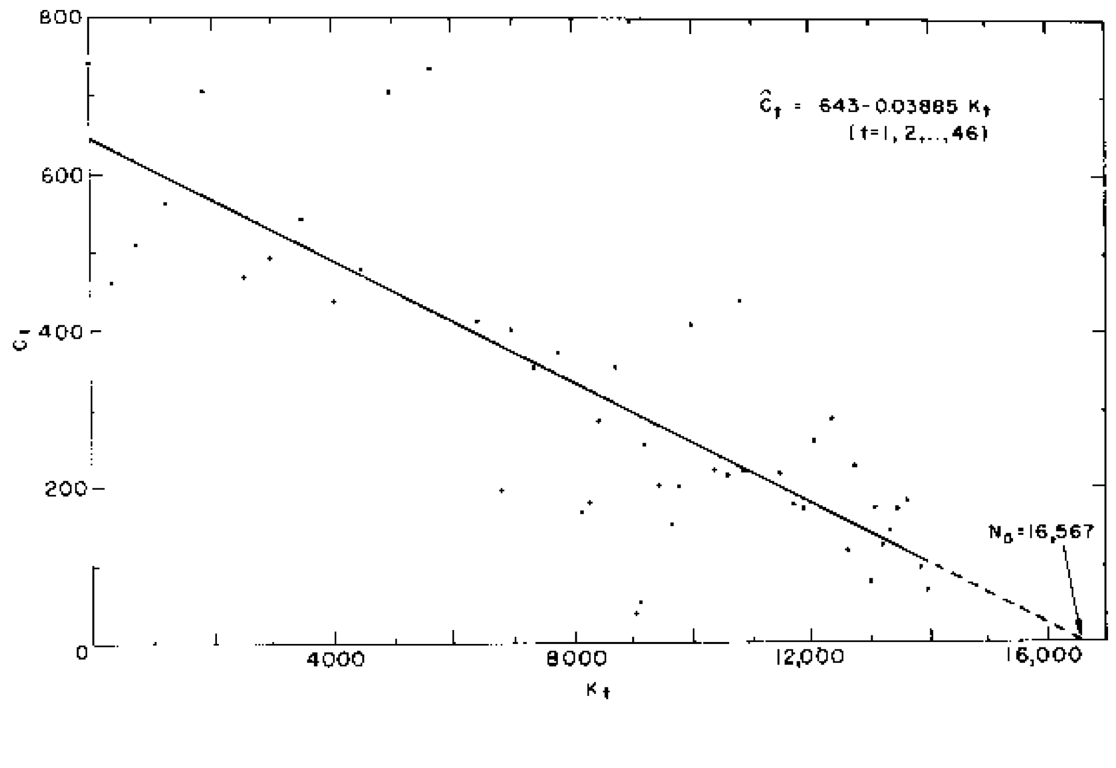

Figure 3.—Leslie plot of catches of unmarked white shrimp. Ordinate is catch in tow t (C_t), and abscissa is cumulative catch to start of tow t (K_t).

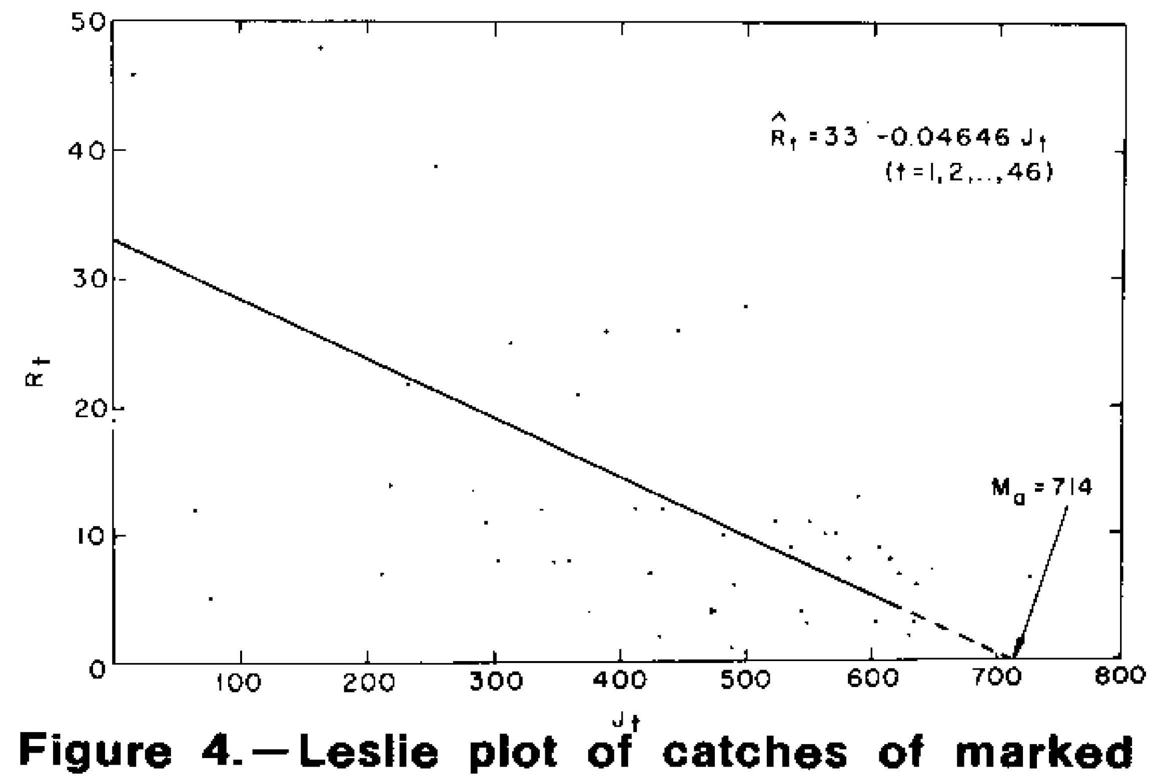

Figure 4.—Leslie plot of catches of marked white shrimp. Ordinate is recaptures in tow t (R_t) and abscissa is cumulative catch to start of tow t (J_t).

in which

f=Total number of tows.

The instantaneous rate of "other losses", y, was estimated by

$$y = c'f - p.$$

Other losses could include emigration, natural mortality, and marking mortality. None of the 50 marked shrimp held in the pen died during the experiment,

Table 1.—Estimates of initial population[1], number caught, number of immigrants and number of other losses of white shrimp in a tidal marsh pond.

Type of estimate	Calculated values
Modified Petersen	
Initial population, $\hat{N}$	45,535(42,029-49,041)
Leslie	
Apparent initial population, N_a	16,567(15,139-18,685)
Ketchen	
Initial population, $\hat{N}$	38,899
Number caught, C	13,989
Number of immigrants, $\hat{I}$	6,434
Number of other losses, $\hat{O}$	25,294

[1]95% confidence limits are given in parentheses.

but one of the 50 unmarked shrimp held as a control died. It was assumed, therefore, that marking mortality was negligible, and that "other losses" included only emigration and natural mortality. The instantaneous rate of immigration, z, was estimated by

$$z = c'f - cf.$$

The apparent initial population, (N_a, Table 1) was estimated by the Leslie method (Figure 3), and an estimate of the initial population ($\hat{N}$, Table 1), was obtained by

$$\hat{N} = N_a\ (p+y-z)\ /p.$$

The average population, N, was estimated from

$$\overline{N} = C_u/p$$

in which

C_u = Total number of unmarked shrimp caught.

An estimate of the number of immigrants ($\hat{I}$, Table 1), was obtained by

$$\hat{I} = z\overline{N}$$

and the estimated number of "other losses" ($\hat{O}$, Table 1) was obtained by

$$\hat{O} = y\overline{N}.$$

It is obvious that the total number of unmarked animals caught is

$$C_u = p\overline{N}.$$

As developed above, this method gives $\hat{N}$ for unmarked animals only. In situations in which large populations are sampled, the discrepancy caused by exclusion of marked animals from the estimate is slight, but for smaller populations adjustments may be desirable to account for marked animals. Such adjustments could be made by (1) adding the total number of marked animals to the Ketchen estimate of $\hat{N}$, and by (2) calculating $\overline{N}$ from

$$\overline{N} = (C_u + C_m)/p$$

in which

C_m = total number of marked animals caught.

The large discrepancy between the Petersen and Leslie estimates ($\hat{N}$ and N_a, Table 1) would be corrected partially by such adjustments. We believe that the difference observed also can be attributed in part to (1) inflation of the Petersen estimate by immigration, and (2) depression of the Leslie estimate by "other losses" (emigration and natural mortality).

Though the area was blocked during the study, the net was ripped and may have been lifted off the bottom on several occasions by tidal currents and by the wakes of tugs pushing barges on the Intracoastal Waterway. Though the net was quickly repaired, there was still ample opportunity for emigration and immigration to occur. Natural mortality during the experiment in unknown, but it is probable that such losses were of lesser consequence because the study was of short duration. Losses due to fishing were exceeded by "other losses" (emigration and natural mortality). Marking mortality was assumed to be negligible in that no mortalities occurred in marked shrimp held in the pen during the study (see section on Study Area and Methods). Consequently, we believe that emigration was chiefly responsible for the decline in catch during the study.

Two additional sources for error remain to be considered. First, heterogeneity of variance was apparent in the data for marked animals (Figure 4). This may have biased our least squares regression estimates for marked shrimp and other estimates derived therefrom. Shrimp catch data usually exhibit greater variability at higher levels of abundance than at lower levels. However, the catch data for unmarked shrimp (Figure 3) do not appear to be heterogeneous. Another possible source of error would be differences in length-frequency between marked and unmarked populations of shrimp. There was a slight difference between the length distributions (Figure 2) of marked and unmarked shrimp in the study, but it was considered to be of little consequence.

In future studies, greater care will be taken in preventing shrimp migrations. Areas less subject to tidal extremes and wakes of boats will be chosen for study. In such cases, the "other losses" should represent natural mortality, provided that losses due to marking are negligible.

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